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Research Article

A Study on Reinforcing Sand Concrete with Sisal Fibres for Sustainable Building Solutions

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Abstract – This experimental study explores the impact of incorporating sisal fibers into sand concrete (SC) at varying ratios (0.05%, 0.10%, and 0.15%). Comprehensive tests were conducted on each sample to assess workability, flexural strength, compressive strength, and ultrasonic pulse velocity. The findings reveal a noteworthy enhancement in flexural strength with the addition of sisal fibers, highlighting a substantial improvement in this crucial property. However, it is observed that the inclusion of sisal fibers poses challenges to certain aspects of concrete composites. Despite potential obstacles, the significant improvement in flexural strength opens new avenues for the utilization of sisal-fiber-reinforced sand concrete in diverse building and construction applications. This study provides valuable insights into optimizing the incorporation of sisal fibers, contributing to advancements in the development of high-performance and sustainable construction materials.

Keywords – Sand Concrete, Workability, Flexural Strength, Compressive Strength And Ultrasonic Pulse Velocity.

I. Introduction

In recent years, the field of construction materials has witnessed a growing emphasis on sustainability, prompting researchers to explore innovative solutions that not only address environmental concerns but also enhance the performance of construction components. One such focus has been on sand concrete, a composition recognized for its economic and ecological significance, particularly in regions where gravel resources are limited [1]. This paper delves into the realm of sand concrete, investigating the potential of sisal fiber incorporation as a sustainable and structurally beneficial enhancement. Sand concrete, characterized by its high sand content, serves as a versatile alternative to traditional concrete [2], and shows promising results in recycling quarry waste as fine aggregate while repurposing quarry waste [3], [4]. This study explores the unique properties of sand concrete, shedding light on the historical development of this material and its distinctive composition. The introduction of sisal fiber into this equation further augments the environmental sustainability of sand concrete.

In the context of this study, the incorporation of sisal fiber underscores its widespread availability as a plant-derived resource, a characteristic observed globally [5]. Simultaneously, the utilization of plant fibers in composite materials stands out as an environmentally safe practice, devoid of any health risks to the ecosystem [6]. Sisal fiber, characterized by its abundant cellulose content, exhibits not only heightened tensile and flexural strength but also proves to be a cost-effective option when compared to various other plant fibers [7]. What truly sets sisal fibers apart from their natural counterparts is their exceptional resistance to water absorption, a distinguishing feature that proves advantageous in scenarios where mitigating moisture impact is paramount.

The primary goal of this experimental study is to assess and optimize the properties of sand concrete (SC) by incorporating sisal fibers at varying ratios (0.05%, 0.10%, and 0.15%). Through comprehensive testing, the study aims to understand the impact of sisal fiber inclusion on workability, flexural strength, compressive strength, and ultrasonic pulse velocity. The overarching objective is to identify an optimal balance that enhances flexural strength, despite potential challenges in other concrete composite properties. The ultimate aim is to contribute to the development of high-performance and sustainable construction materials by leveraging the benefits of sisal-fiber-reinforced sand concrete.

II. Materials and Method

A. *sand*

Crushed sand (CS) and river sand (RS), presents continuous particle size distribution ranging from 0.08 to 5 mm. The particle size distributions of the various sands used are shown in Figure 1.Table 1 shows the set of physical properties of the sand types used.

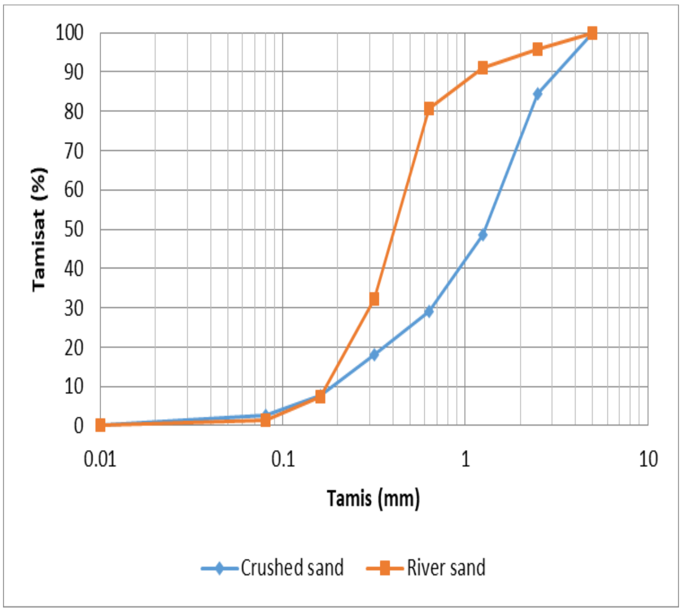

Fig. 1 Granular size analysis of sand

Table 1. Physical properties of the sand used

	(CS)	(RS)
Apparent density (g/m^3)	1.48	1.61
Specific density (g/m^3)	2.60	2.50
Fineness modulus	3.03	1.92
Compactness (CP)	56.92	64.40
Sand equivalent	97.63	78

A. *Cement*

The cement employed is ordinary Portland cement (type II) of class 42.5, also known as ‘‘CPJ CEM II/A”.

The physical characteristics are the following: absolute density of 3.1 g / cm^3 and 370 m^2/kg fineness. The chemical compositions of the cement used along within Table 2.

Table 2. Chemical compositions of cement

	(%)
SiO_2	20,52
CaO	63,86
Al2O$_3$	5,13
Fe_2O_3	3,36
MgO	1,27
Na_2O	0,14
K_2O	0,76
SO_3	2,26
Cl-	0,027
L.O.I	1,09

B. *Water*

Water temperature of 20 ± 1 °C conforms to the requirements of standard NFP 18-404.

C. *Fibres*

Sisal fibres with a length of 20 mm were used in this study. A typical stress–strain curve for sisal fibre with a length of 20 mm is presented in Figure 2.

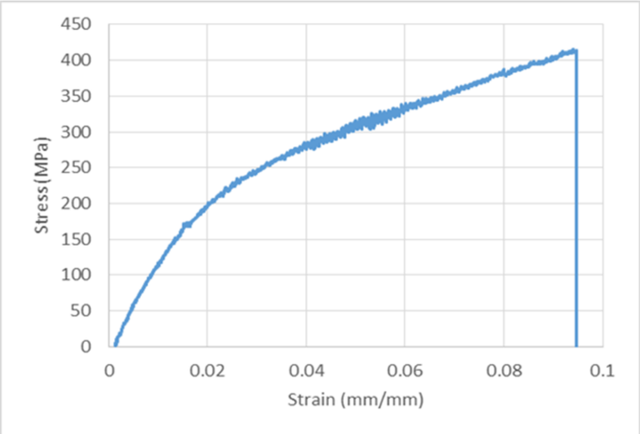

Fig. 2 Typical stress–strain curve for sisal fibres

D. *Filler*

Limestone filler is a finely ground mineral rock that meets compactness standards according to NF P18-508 (1995) regarding mineral additions to limestone. The limestone filler was sifted through a sieve with an opening of 0.08 mm. The filler is an important component of sand concrete [8]. The physical properties of the filler are shown in Table 3.

Table 3 Physical properties of limestone filler

Apparent density (kg/m^3)	1083
Specific density (kg/m^3)	2700
Specific surface (cm^2/g)	5360

E. *Superplasticizer*

The superplasticizer used is a water-reducing ‘Superior 126’ type. It is a liquid solution that is diluted with water in conformity with the EN 934-2 standard.

F. *Formulation of Sand Concrete*

The mix proportions adopted were prepared from a formulation based on an experimental approach derived from previous works on sand concrete [3], [4], [17]–[26], [9], [27], [28], [10]–[16].

The mixing proportion approach used here for sand concrete was aimed at optimizing the compactness of the granular skeleton. The chosen cement mix(C) was fixed at 350 kg/m^3 [1], [29]. have kept a constant W/C for all the mixes. The quantity of sand [S] being determined according to the following equation: [1], [2]

$$V_s = 1000\,\gamma - V_c \quad (1)$$

γ: Compactness coefficient

Sisal fibres with lengths of 20 mm and different percentages of the total dry weight of the mixture were used for all samples, the study was conducted on four different mixtures as follows:

- SC: Does not contain sisal fibres.
- 0.05% F: Contains 0.05% sisal fibres.
- 0.10% F: Contains 0.10% sisal fibres.
- 0.15% F: Contains 0.15% sisal fibres.

G. *Sand Concrete mixing and conservation*

To obtain a high level of homogeneity in the sand concrete, an initial dry mixing was undertaken, followed by a second mixing after introducing the mixing water. Mixing then continued for each composition until obtaining a homogeneous mix according to the EN 196-1 Standard. The tightening was achieved, thanks to vibration on a vibrating table. These compound samples were then removed from their molds after 24 hours, and immersed in water under a constant temperature until test day.

H. *Experimental methods*

- Workability was measured in accordance with the NF P 18-452 standard. The test consisted of a metal parallelepiped box (7.5 cm x 7.5 cm x 15 cm) placed on rubber supports, fitted with a vibrator and equipped with a removable partition. The higher the flow rate of the mixture, the shorter the flow time.

- Flexural strength are tested at 7and 28 days on prismatic specimens (7×7×28) cm^3 in according with standard NF EN 12390-6. The flexural strength was obtained by selecting three-points for the sample, the maximum flexural strength of sand concrete determined from the maximum load after the first crack.

- Compressive strength is tested at 7 and 28 days on half-prism obtained after rupture specimens in according with standard NF EN 12390-3.The compressive strength of sand concrete determined from the maximum load.

- Ultrasonic pulse velocity test (UPV) was used following NF EN 12 504-4 standard. It's consists of holding the two poles for computing the pulse velocity.

III. RESULTS AND DISCUSSION

A. *Workability*

The workability of the mixtures was calculated in terms of flow time under the influence of vibration. All flow values for the samples are shown in Figure 3.We observed that when the percentage of sisal fibres increased, the workability decreased due to the composition and shape of the fibres that affect workability. This condition is in accordance with the findings of Siva Bala et al. [30] that workability decreased when sisal fibres were increased in self-compacting concrete. Several studies show how adding fibre in the cement matrix affects the workability [31], [32].

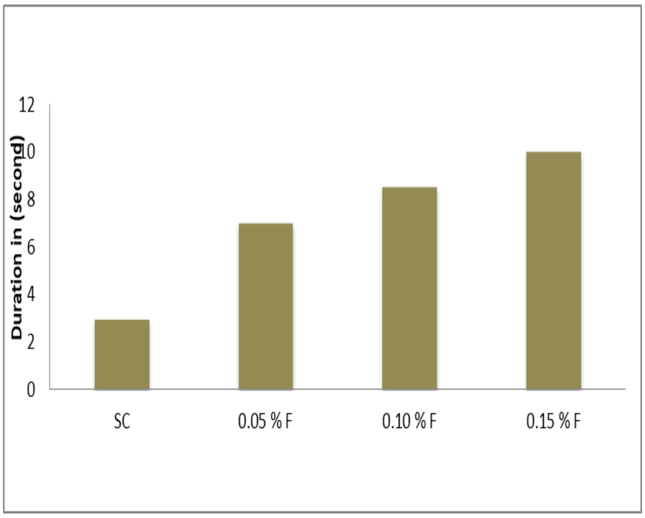

Fig. 3 Workability of mixtures

B. *Flexural strength*

Figure 4 displays all the flexural strength results obtained for all samples at 7, 28, and 120 days. An improvement in flexural strength was observed when adding unmodified sisal fibers in the following rates: as there was a good improvement in the flexural strength, Especially at 0.10% F as the optimum ratio of sisal fibers. As previous studies have shown that the addition of sisal fibers in concrete improves well the flexural [33], [34] In general, the addition of vegetable fibers in concrete and mortar had a role in increasing tensile and flexural strength [35].

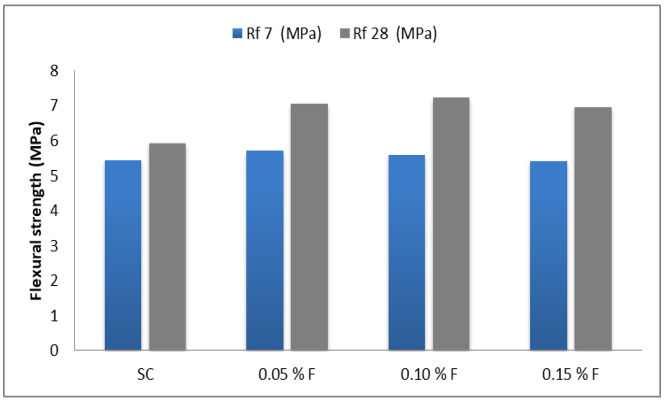

Fig .4 Flexural strength of samples

C. *Compressive strength*

The compressive strength of sand concrete was measured at 7 and 28 days. Figure 5 displays all the results obtained. When sisal fibers were added to sand concrete, there was an overall decrease in compressive strength compared to the reference sand concrete (SC), and the higher the percentage of fibers, the lower the compressive strength. This weakness often occurs when plant fibers are added, especially those not processed. Many studies show that the compressive strength of concrete decreases when plant fibers are added [27,49,50].

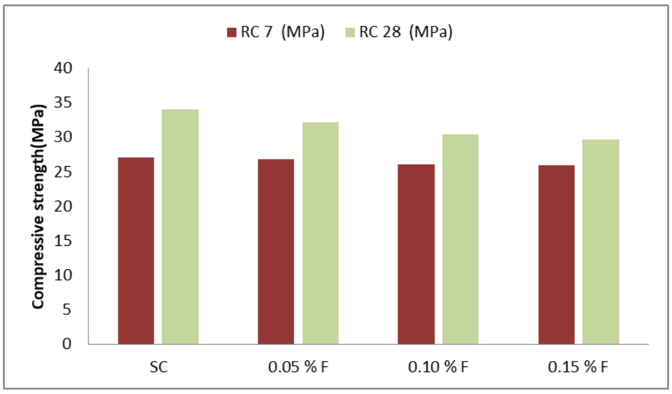

Fig .5 Compressive strength of samples

D. *Ultrasonic pulse velocity test*

Figure 6 shows all the UPV values of the studied compounds at 7 and 28 days. Where it becomes clear to us that when adding sisal fibers to sand concrete, we notice a decrease in the Ultrasonic pulse velocity. The higher the fiber ratio, the lower the UPV. This decrease in the Ultrasonic pulse velocity propagation when adding untreated sisal fibers is due to the nature of the cellulosic sisal fibers tissues and also the weak adhesion between the sisal fibers and the cement matrix, which leads to voids and pores that contribute to reducing UPV.

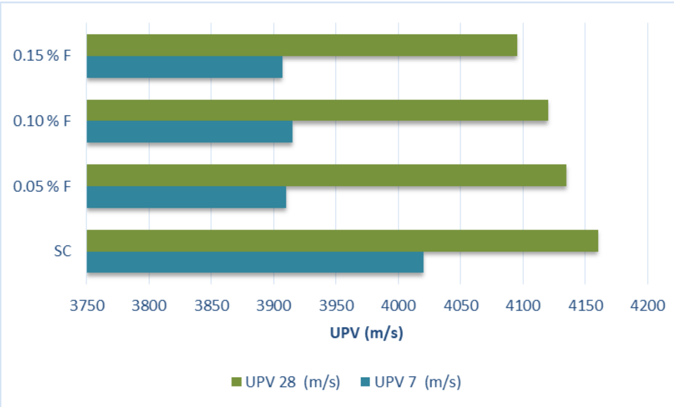

Fig .6 Ultrasonic pulse velocity of samples

IV. CONCLUSION

The findings from this study on enhancing sand concrete properties through the incorporation of sisal fibers reveal nuanced outcomes. While there is a slight reduction observed in workability, compressive strength, and ultrasonic pulse velocity (UPV) of the sand concrete with the addition of sisal fibers, a substantial enhancement is evident in flexural strength. This suggests that while the inclusion of sisal fibers may pose challenges to certain aspects of concrete performance, it significantly reinforces the material's ability to withstand bending forces. These results not only contribute valuable insights for optimizing the proportions of sisal fibers in sand concrete but also point towards promising avenues for further exploration. The identified improvements in flexural strength pave the way for innovative applications of sisal fibers in diverse cement compounds, underscoring the potential for future advancements in sustainable and high-performance construction materials.

REFERENCES

[1] K. Gadri and A. Guettala, "Evaluation of bond strength between sand concrete as new repair material and ordinary concrete substrate (The surface roughness effect)," *Constr. Build. Mater.*, vol. 157, no. May, pp. 1133–1144, 2017, doi: 10.1016/j.conbuildmat.2017.09.183.

[2] K. Gadri and A. Guettala, "Study of the adaptation of the sand concrete as repair material associated with an ordinary," vol. 3, pp. 13–20, 2017.

[3] O. Jaradat, K. Gadrı, and A. Guettala, "Study the mechanical and physical properties of sand concrete using crushed limestone sand," *J. Mater. Electron. Devices*, vol. 3, no. 3, pp. 26–29, 2021.

[4] O. Jaradat, K. Gadri, and A. Guettala, "Influence of crushed sand on the dynamic modulus of elasticity of sand concrete," *J. Phys. Chem. Funct. Mater.*, vol. 5, no. July, pp. 65–68, 2022, doi: 10.54565/jphcfum.1070879.

[5] A. M. Brandt, "Fibre reinforced cement-based (FRC) composites after over 40 years of development in building and civil engineering," *Compos. Struct.*, vol. 86, no. 1–3, pp. 3–9, 2008.

[6] A. Campos *et al.*, "Morphological, mechanical properties and biodegradability of biocomposite thermoplastic starch and polycaprolactone reinforced with sisal fibers," *J. Reinf. Plast. Compos.*, vol. 31, no. 8, pp. 573–581, 2012.

[7] K. Joseph, R. D. Tolêdo Filho, B. James, S. Thomas, and L. H. de Carvalho, "a Review on Sisal Fiber Reinforced Polymer Composites," *Rev. Bras. Eng. Agrícola e Ambient.*, vol. 3, no. 3, pp. 367–379, 1999, doi: 10.1590/1807-1929/agriambi.v3n3p367-379.

[8] M. Bédérina, M. M. Khenfer, R. M. Dheilly, and M. Quéneudec, "Reuse of local sand: Effect of limestone filler proportion on the rheological and mechanical properties of different sand concretes," *Cem. Concr. Res.*, vol. 35, no. 6, pp. 1172–1179, 2005, doi: 10.1016/j.cemconres.2004.07.006.

[9] O. Jaradat, K. Gadri, B. A. Tayeh, and A. Guettalaa, "Influence of sisal fibres and rubber latex on the engineering properties of sand concrete," *Struct. Eng. Mech.*, vol. 80, no. 1, pp. 47–62, 2021.

[10] O. Jaradat, K. Gadri, and A. Guettala, "The effect of partial replacement of crushed sand on the properties of sand concrete," *First Int. Recycl. Cem. Based Compos. Congr. REC*, no. March 2022, pp. 1–5, 2022.

[11] O. Jaradat, K. Gadri, and A. Guettala, "Evaluation of the effect of crushed sand on the engineering properties of concrete sand," 2022.

[12] O. Jaradat, K. Gadri, A. Sirhan, and A. Guettala, "Characteristics of sand concrete using quarry sand," *1st Int. Conf. Innov. Acad. Stud. ICIAS*, no. 3, pp. 419–423, 2022.

[13] O. Jaradat, K. Gadri, A. Sirhan, and A. Guettala, "Properties of sand concrete with and without crushed sand," *2nd Int. Conf. Eng. Appl. Nat. Sci.*, no. mm, pp. 450–453, 2022.

[14] O. Jaradat, K. Gadri, and A. Guettala, "The effect of crushed sand on the compactness of sand concrete," *Second Int. Conf. Civ. Eng. ICCE'2021*, pp. 1–7, 2021.

[15] O. Jaradat, K. Gadri, and A. Guettala, "Study of the Dynamic Modulus of Elasticity of Sand Concrete Containing Crushed Sand," *Int. Conf. New Trends Sci. Appl.*, no. type II, pp. 22–24, 2021.

[16] O. Jaradat, K. Gadri, A. Sirhan, and A. Guettala, "Mechanical behavior of sand concrete," p. 2022,

2022.
[17] O. Jaradat, K. Gadri, A. Sirhan, and A. Guettala, “Performance of sand concrete with limestone filler,” 2023.
[18] O. Jaradat, K. Gadri, and A. Guettala, “The effect of using limestone fillers on the mechanical behaviour of sand concrete,” p. 2023, 2023.
[19] O. Jaradat, K. Gadri, and A. Guettala, “limestone fillers’ effects on the engineering properties of sand concrete,” 2023.
[20] O. Jaradat, K. Gadri, and A. Guettala, “Effect of limestone filler on the sand concrete’s compactness,” *1st Int. Conf. Recent Acad. Stud.*, p. 2023, 2023.
[21] O. Jaradat, K. Gadri, and A. Guettala, “Impact of crushed sand replacement on the properties of sand concrete,” p. 31, 2023.
[22] O. Jaradat, K. Gadri, and A. Guettala, “Evaluation of the influence of crushed sand on the qualities of concrete sand,” 2023.
[23] M. Khattab, O. Jaradat, S. Hachemi, H. Suleiman, and H. Benzetta, “Mechanical, physical and environmental performance of sustainable concrete containing marble wastes,” *Secur. Manag. Mod. Civ. Eng.*, vol. 2, no. 2, pp. 1–10, Jun. 2023, doi: 10.58396/smmce020202.
[24] O. Jaradat, K. Gadri, and A. Guettala, “Technical properties of sand concrete with the addition of limestone filler,” 2023.
[25] O. Jaradat, K. Gadri, B. Tayeh, A. Maglad, and A. Guettala, “Effectiveness of bond strength between normal concrete as substrate and latex-modified sand concrete reinforced with sisal fibers as a repair material,” *Adv. Concr. Constr.*, vol. 15, no. 6, pp. 431–444, 2023, doi: 10.12989/acc.2023.15.6.431.
[26] O. Jaradat, K. Gadri, and A. Guettala, “Investigate the characteristics of sand concrete using crushed limestone sand,” p. 68, 2023.
[27] O. Jaradat, M. Shakarna, A. Sirhan, K. Gadri, and M. Khattab, “Effect of stone sludge incorporation on cement brick production,” *2nd Int. Conf. Contemp. Acad. Res.*, p. 63, 2023.
[28] O. Jaradat, “L’effet de l’incorporation des fibres végétales sur les propriétés physico-mécaniques des bétons de sable modifiés au latex destinés à la réparation.” Faculté des Sciences et de la technologie, 2022. [Online]. Available: http://archives.univ-biskra.dz/handle/123456789/23910
[29] Chauvin and Grimaldi, “Les bétons de sable,” *Bull. liaison des Lab. des ponts chaussées*, no. 157, pp. 9–15, 1988.
[30] P. Siva Bala and G. Vaisakh, “Mechanical Properties of Self Compacting Concrete Containing Crushed Sand and Sisal Fiber,” *Int. J. Appl. Environ. Sci.*, vol. 13, no. 1, pp. 71–81, 2018, [Online]. Available: http://www.ripublication.com
[31] A. M. Neville and J. J. Brooks, *Concrete technology*. Longman Scientific & Technical England, 1987.
[32] O. Gencel, W. Brostow, T. Datashvili, and M. Thedford, “Gencel O, Brostow W, Datashvili T, Thedford M. Workability and mechanical performance of steel fiber-reinforced self-compacting Concrete with Fly Ash. Compos Interf 2011;18:169–84.,” *Compos. interfaces*, vol. 18, no. 2, pp. 169–184, 2011.
[33] L. Nilsson, “Reinforcement of concrete with sisal and other vegetable fibres,” *NASA STI/Recon Tech. Rep. N*, vol. 76, p. 30405, 1975.
[34] D. G. Swift and R. B. L. Smith, *Sisal fibre reinforcement of cement paste and concrete*. 1978.
[35] M. S. Ammari, B. Belhadj, M. Bederina, A. Ferhat, and M. Quéneudec, “Contribution of hybrid fibers on the improvement of sand concrete properties: Barley straws treated with hot water and steel fibers,” *Constr. Build. Mater.*, vol. 233, p. 117374, 2020, doi: 10.1016/j.conbuildmat.2019.117374.
[36] L. M. Zhou, Y. W. Mai, L. Ye, and J. K. Kim, “Techniques for evaluating interfacial properties of fibre-matrix composites,” in *Key Engineering Materials*, 1995, vol. 104, pp. 549–600.
[37] M. Bederina, M. Gotteicha, B. Belhadj, R. M. Dheily, M. M. Khenfer, and M. Queneudec, “Drying shrinkage studies of wood sand concrete - Effect of different wood treatments,” *Constr. Build. Mater.*, vol. 36, pp. 1066–1075, 2012, doi: 10.1016/j.conbuildmat.2012.06.010.